Claims:

1. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

using a non-low deformation resistance region forming means which forms a non-low deformation resistance region by increasing the deformation resistance which is lowered in the low deformation resistance region, the non-low deformation resistance region is formed along the low deformation resistance region.

2. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region which traverses the metal body by locally lowering the deformation resistance of a metal body which extends in one direction and by deforming the low deformation resistance region by shearing, wherein

using a non-low deformation resistance region forming means which forms a non-low deformation resistance region by increasing the deformation resistance which is lowered in the low deformation resistance region, the non-low deformation resistance region is formed along at least one side periphery of the low deformation resistance region.

3. A method for processing a metal body according to claim 2, wherein the metal body is moved along the extending direction and, at the same time, the non-low deformation resistance region is formed by the non-low deformation resistance region forming means along side peripheries of the low deformation resistance region at a downstream side in the moving direction.

4. A method for processing a metal body according to any one of claims 1 to 3, wherein the non-low deformation resistance region forming means includes cooling means which cools the metal body.

5. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the low deformation resistance region is formed in a vacuum.

6. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the low deformation resistance region is formed in a high pressure atmosphere.

7. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the low deformation resistance region is formed in an active gas atmosphere.

8. A method for processing a metal body according to claim 7, wherein the active gas is nitrogen gas.

9. A method for processing a metal body according to claim 7, wherein the active gas is methane gas and/or carbon monoxide gas.

10. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

a powdery material is sprayed to the low deformation resistance region.

11. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

ion doping is applied to the low deformation resistance region.

12. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the low deformation resistance region is formed by applying second heating to the metal body after applying first heating for a given time.

13. A method for processing a metal body according to any one of claims 1 to 11, wherein the low deformation resistance region is formed by applying second heating to the metal body after applying first heating for a given time.

14. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the low deformation resistance region is formed in a non-constraining region of constraining means which constrains the metal body heated to a high temperature.

15. A method for processing a metal body according to any one of claims 1 to 11, wherein the low deformation resistance region is formed in a non-constraining region

of constraining means which constrains the metal body heated to a high temperature.

16. A method for processing a metal body according to any one of claims 5 to 14, wherein the metal body is quenched after the deformation by shearing.

17. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the low deformation resistance region is formed by heating the metal body and, at the same time, the metal body is quenched after the low deformation resistance region is deformed by shearing.

18. A method for processing a metal body according to any one of claims 5 to 11, wherein the low deformation resistance region is formed by heating the metal body and, at the same time, the metal body is quenched after the low deformation resistance region is deformed by shearing.

19. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing,

the low deformation resistance region is formed in

the metal body which is immersed in a liquid.

20. A method for processing a metal body according to claim 19, wherein the low deformation resistance region is formed by heating the metal body in the liquid.

21. A method for processing a metal body according to claim 20, wherein in forming the low deformation resistance region, the heat conductivity of a periphery of the low deformation resistance region is lowered.

22. A method for processing a metal body according to claim 20, wherein in forming the low deformation resistance region, bubbles are generated in a periphery of the low deformation resistance region.

23. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure by forming a low deformation resistance region where the deformation resistance is locally lowered in the metal body and by deforming the low deformation resistance region by shearing, wherein

the metal body which has the finer metal structure is subjected to plastic forming without turning the metal structure into coarser grain structure.

24. A method for processing a metal body according to any one of claims 1 to 23, wherein the metal body which has the finer metal structure is subjected to plastic forming without turning the metal structure into coarser grain structure.

25. A method for processing a metal body according

to claim 23 or claim 24, wherein the plastic forming is performed in a heated state for a short time which does not turn the metal structure of the metal body into coarser grain structure.

26. A method for processing a metal body according to any one of claims 23 to 25, wherein the aging treatment is performed without turning the metal structure into coarser grain structure after the metal structure is subjected to the plastic forming.

27. A method for processing a metal body according to any one of claims 1 to 26, wherein the metal body is subjected to the carburizing treatment.

28. A method for processing a metal body according to any one of claims 1 to 27, wherein the metal structure of the metal body is turned into the finer grain structure by stretching the low deformation resistance region.

29. A method for processing a metal body according to any one of claims 1 to 27, wherein the metal structure of the metal body is turned into the finer grain structure by compressing the low deformation resistance region.

30. A method for processing a metal body according to any one of claims 6 to 29, wherein the metal body is formed in a cylindrical body having a hollow portion and the hollow portion is held in a reduced pressure state.

31. A method for processing a metal body according to any one of claims 1 to 29, wherein the metal body is formed in a cylindrical body having a hollow portion and the hollow

portion is held in a high pressure state.

32. A method for processing a metal body according to any one of claims 1 to 31, wherein a forming guide body which forms the metal body into a given shape is brought into contact with the low deformation resistance region.

33. A method for processing a metal body according to claim 32, wherein the forming guide body constitutes heating means which heats the metal body.

34. A method for processing a metal body according to claim 32, wherein the forming guide body constitutes cooling means which cools the metal body.

35. A method for processing a metal body according to any one of claims 1 to 34, wherein the low deformation resistance region is formed in a transverse manner in the metal body which is extended in one direction, and the low deformation resistance region is moved along the extending direction of the metal body.

36. A method for processing a metal body according to any one of claims 1 to 34, wherein the low deformation resistance region traverses the metal body, and one of non-low deformation resistance regions of the metal body which sandwich the low deformation resistance region has a position thereof fluctuated relative to another non-low deformation resistance region is fluctuated thus deforming the low deformation resistance region by shearing.

37. A method for processing a metal body according to claim 36, wherein the fluctuation of the position is a

vibratory motion having vibratory motion components which allow the vibratory motion of one non-low deformation resistance region relative to another non-low deformation resistance region in the direction substantially orthogonal to the extending direction of the metal body.

38. A method for processing a metal body according to claim 36, wherein the fluctuation of the position is a one-way rotational motion which allows the rotation of one non-low deformation resistance region relative to another non-low deformation resistance region about a rotary axis which is arranged substantially parallel to the extending direction of the metal body.

39. A method for processing a metal body according to claim 36, wherein the fluctuation of the position is a both-way rotational motion which allows the rotation of one non-low deformation resistance region relative to another non-low deformation resistance region about a rotary axis which is arranged substantially parallel to the extending direction of the metal body.

40. A method for processing a metal body being characterized in that a metal body in a heated state which is extended in one direction is moved along the extending direction, the metal body is cooled by allowing the metal body to pass through cooling means, and the cooled metal body is subjected to a vibratory motion thus turning the metal structure in the metal body into the finer grain structure by deforming the metal structure by shearing before

the metal body is allowed to pass through the cooling means.

41. A method for processing a metal body being characterized in that in performing solution heat treatment by quenching a metal body which is heated up to a temperature for performing the solution heat treatment using cooling means, the metal body at a quenched portion is deformed by shearing thus turning the metal structure into finer metal structure and the solution heat treatment is performed.

42. A method for processing a metal body according to claim 41, wherein the deformation of the metal body by shearing is performed by imparting a vibratory motion which includes vibratory motion components which generate the vibratory motion in the direction substantially orthogonal to the extending direction of the metal body which is extended in one direction to the metal body.

43. A method for processing a metal body according to claim 41, wherein the deformation of the metal body by shearing is performed by imparting a one-way rotational motion which generates the rotation about a rotational axis substantially parallel to the extending direction of the metal body which is extended in one direction to the metal body.

44. A method for processing a metal body according to claim 41, wherein the deformation of the metal body by shearing is performed by imparting a both-way rotational motion which generates the rotation about a rotational axis substantially parallel to the extending direction of the

metal body which is extended in one direction to the metal body.

45. A method for processing a metal body according to any one of claims 41 to 44, wherein the metal body whose metal structure is turned into the finer grain structure is formed into a given shape by performing plastic forming under a condition which prevents the metal structure from becoming coarse.

46. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure in which a first low deformation resistance region and a second low deformation resistance region which traverse the metal body are formed in a spaced-apart manner by a given distance by locally lowering the deformation resistance of the metal body which extends in one direction, a non-low deformation resistance region which increases the deformation resistance larger than the deformation resistance of the first low deformation resistance region and the second low deformation resistance region is formed between the first low deformation resistance region and the second low deformation resistance region using non-low deformation resistance region forming means, and a vibratory motion including vibratory motion components in the direction orthogonal to the extending direction of the metal body is imparted to the non-low deformation resistance region thus deforming the first low deformation resistance region and the second low deformation resistance region by shearing.

47. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure in which a first low deformation resistance region and a second low deformation resistance region which traverse the metal body are formed in a spaced-apart manner by a given distance by locally lowering the deformation resistance of the metal body which extends in one direction, a non-low deformation resistance region which increases the deformation resistance larger than the deformation resistance of the first low deformation resistance region and the second low deformation resistance region is formed between the first low deformation resistance region and the second low deformation resistance region using non-low deformation resistance region forming means, and a one-way rotational motion about a rotary axis substantially parallel to the extending direction of the metal body is imparted to the non-low deformation resistance region thus deforming the first low deformation resistance region and the second low deformation resistance region by shearing whereby the metal structure of the metal body is turned into the finer grain structure.

48. A method for processing a metal body which turns the metal structure of the metal body into the finer grain structure in which a first low deformation resistance region and a second low deformation resistance region which traverse the metal body are formed in a spaced-apart manner by a given distance by locally lowering the deformation resistance of

the metal body which extends in one direction, a non-low deformation resistance region which increases the deformation resistance larger than the deformation resistance of the first low deformation resistance region and the second low deformation resistance region is formed between the first low deformation resistance region and the second low deformation resistance region using non-low deformation resistance region forming means, and a both-way rotational motion about a rotary axis substantially parallel to the extending direction of the metal body is imparted to the non-low deformation resistance region thus deforming the first low deformation resistance region and the second low deformation resistance region by shearing.

49. A method for processing a metal body according to any one of claims 46 to 48, wherein the metal body is moved along the extending direction.

50. An apparatus for processing a metal body comprising:

low deformation resistance region forming means which forms a low deformation resistance region which traverses the metal body by locally lowering the deformation resistance of the metal body which extends in one direction;

non-low deformation resistance region forming means which forms non-low deformation resistance region by increasing the deformation resistance which is lowered in the low deformation resistance region, and

displacement applying means which displaces one side

of the metal body which sandwiches the low deformation resistance region with another side of the metal body relative to another side of the metal body, wherein

the apparatus turns the metal structure of the metal body into the finer grain structure by deforming the low deformation resistance region by shearing along with the displacement applied by the displacement applying means.

51. An apparatus for processing a metal body according to claim 50, wherein the displacement applying means applies a vibratory motion including vibratory motion components in the direction which intersect the extending direction of the metal body to the metal body.

52. An apparatus for processing a metal body according to claim 50, wherein the displacement applying means applies a one-way rotational motion including about a one-way rotational axis substantially parallel to the extending direction of the metal body to the metal body.

53. An apparatus for processing a metal body according to claim 50, wherein the displacement applying means applies a both-way rotational motion including about a both-way rotational axis substantially parallel to the extending direction of the metal body to the metal body.

54. An apparatus for processing a metal body according to any one of claims 50 to 53, wherein the low deformation resistance region forming means is heating means which heats the metal body to a given temperature or more.

55. An apparatus for processing a metal body according

to any one of claims 50 to 54, wherein the non-low deformation resistance region forming means is cooling means which cools the metal body.

56. An apparatus for processing a metal body according to any one of claims 50 to 55, wherein the apparatus includes supply means which supplies the metal body along the extending direction.

57. An apparatus for processing a metal body according to any one of claim 56, wherein the low deformation resistance region forming means includes preheating means which heats the metal body to a second heating temperature after heating the metal body to a first heating temperature and holding the first heating temperature for a given time.

58. An apparatus for processing a metal body according to claim 57, wherein the first heating temperature is a temperature which is necessary for solution heat treatment of the metal body.

59. An apparatus for processing a metal body according to any one of claims 56 to 58, wherein the apparatus includes aging treatment means which performs the aging treatment of the metal body whose metal structure is turned into the finer grain structure by holding the metal body at a temperature which prevents the metal structure from becoming coarser.

60. An apparatus for processing a metal body according to any one of claims 56 to 59, wherein a forming guide body which forms the metal body in a given shape is brought into

contact with the low deformation resistance region.

61. An apparatus for processing a metal body according to claim 60, wherein the forming guide body is heating means which heats the metal body.

62. An apparatus for processing a metal body according to claim 60, wherein the forming guide body is cooling means which cools the metal body.

63. An apparatus for processing a metal body according to any one of claims 56 to 59, wherein the metal body is a cylindrical body having a hollow portion, and the apparatus includes flattening means which cuts the metal body whose metal structure is turned into the finer grain structure along the extending direction of the metal body so as to form the planar body.

64. An apparatus for processing a metal body according to any one of claims 50 to 56, wherein the low deformation resistance region forming means forms the low deformation resistance region in a vacuum.

65. An apparatus for processing a metal body according to any one of claims 50 to 56, wherein the low deformation resistance region forming means forms the low deformation resistance region in a high pressure atmosphere.

66. An apparatus for processing a metal body according to any one of claims 50 to 56, wherein the low deformation resistance region forming means forms the low deformation resistance region in an active gas atmosphere.

67. An apparatus for processing a metal body according

to claim 66, wherein the active gas is nitrogen gas.

68. An apparatus for processing a metal body according to claim 66, wherein the active gas is methane gas and/or carbon monoxide.

69. An apparatus for processing a metal body according to any one of claims 50 to 56, wherein low deformation resistance region forming means includes powdery material spraying means which sprays a powdery material to the low deformation resistance region.

70. An apparatus for processing a metal body according to any one of claims 50 to 56, wherein low deformation resistance region forming means includes ion doping means which dopes ions to the low deformation resistance region.

71. An apparatus for processing a metal body according to any one of claims 50 to 56, wherein the low deformation resistance region forming means forms the low deformation resistance region by heating the metal body which is immersed in the liquid at a given temperature or more.

72. An apparatus for processing a metal body according to claim 71, wherein in forming the low deformation resistance region, the heat conductivity of a periphery of the low deformation resistance region is lowered.

73. An apparatus for processing a metal body according to claim 71, in forming the low deformation resistance region, bubbles are formed in a periphery of the low deformation resistance region.

74. An apparatus for processing a metal body

comprising:

moving means which moves a metal body which extends in one direction along the extending direction;

heating means which heats the metal body to a temperature for performing the solution heat treatment;

cooling means which quenches the metal body heated by the heating means; and

shearing deformation means which deforms a portion of the metal body which is cooled by the cooling means by shearing.

75. An apparatus for processing a metal body according to claim 74, wherein the shearing deformation means applies a vibratory motion which includes vibratory motion components which perform the vibratory motion in the direction substantially orthogonal to the extending direction of the metal body to the metal body.

76. An apparatus for processing a metal body according to claim 74, wherein the shearing deformation means applies a one-way rotational motion which rotates the metal body about a one-way rotating axis substantially parallel to the extending direction of the metal body to the metal body.

77. An apparatus for processing a metal body according to claim 74, wherein the shearing deformation means applies a both-way rotational motion which rotates the metal body about a both-way rotating axis substantially parallel to the extending direction of the metal body to the metal body.

78. An apparatus for processing a metal body

comprising:

moving means which moves the metal body in a heated state extending in one direction along the extending direction;

cooling means which forms a non-low deformation resistance region by increasing the deformation resistance by cooling the metal body; and

vibratory motion applying means which applies a vibratory motion to the non-low deformation resistance region, wherein

the metal structure in the metal body before being supplied to the cooling means is turned into the finer grain structure by the deformation by shearing due to the vibratory motion applied by the vibratory motion applying means.

79. An apparatus for processing a metal body comprising:

first low deformation resistance region forming means which forms a first low deformation resistance region which traverses the metal body by locally lowering the deformation resistance of the metal body which extends in one direction;

second low deformation resistance region forming means which forms a second low deformation resistance region which traverses the metal body by locally lowering the deformation resistance of the metal body at a position spaced apart from the first low deformation resistance region by a given distance;

non-low deformation resistance region forming means

which forms non-low deformation resistance region by increasing the deformation resistance which is lowered in the first low deformation resistance region and the second low deformation resistance region between the first low deformation resistance region and the second low deformation resistance region, and

displacement applying means which applies the displacement for deforming the first low deformation resistance region and the second low deformation resistance region by shearing to the non-low deformation resistance region, wherein

the apparatus turns the metal structure of the first low deformation resistance region and the second low deformation resistance region into the finer grain structure.

80. An apparatus for processing a metal body according to claim 79, wherein the displacement applying means applies a vibratory motion including vibratory motion components in the direction which intersect the extending direction of the metal body to the non-low deformation resistance region.

81. An apparatus for processing a metal body according to claim 79, wherein the displacement applying means applies a one-way rotational motion including about a one-way rotational axis substantially parallel to the extending direction of the metal body to the non-low deformation resistance region.

82. An apparatus for processing a metal body according to claim 79, wherein the displacement applying means applies a both-way rotational motion including about a both-way rotational axis substantially parallel to the extending direction of the metal body to the non-low deformation resistance region.

83. An apparatus for processing a metal body according to any one of claims 79 to 82, wherein the first low deformation resistance region forming means and the second low deformation resistance region forming means are heating means which heats the metal body to a given temperature or more.

84. An apparatus for processing a metal body according to any one of claims 79 to 83, wherein the non-low deformation resistance region forming means is cooling means which cools the metal body.

85. An apparatus for processing a metal body according to any one of claims 79 to 84, wherein the apparatus includes supply means which supplies the metal body along the extending direction.